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(71) Applicant(s)
Ford Global Technologies Inc.

(Incorporated in USA - Michigan)

Suite 911,Parklane Towers East, One Parklane Boulevard, Dearborn, Michigan 48126-2490, United States of America

(72) Inventor(s)
Jeffrey Hepburn

(74) Agent and/or Address for Service
A Messulam & Co
24 Broadway, LEIGH-ON-SEA, Essex, SS9 1BN, United Kingdom

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(54) **Method for monitoring the performance of a NOx trap**

(57) A method and apparatus for on-board monitoring of NO_x trap 32 performance is proposed that uses two HEGO sensors 34,36, one positioned upstream of the NO_x trap, and the other positioned downstream of the NO_x trap. When the engine A/F is reduced from lean to stoichiometric or rich operation to regenerate or purge the NO_x trap 32, the difference in the time it takes for the upstream and downstream HEGO sensors 34,36 to switch from a lean to a rich indication provides a quantitative measure of the amount of NO_x that was stored on the NO_x trap during the previous lean period of operation. This measure is related to an estimated amount of NO_x produced by the engine to infer the operating performance or efficiency of the NO_x trap. The difference in the output voltage of the two sensors 34,36 is compared with a predetermined value to determined when to terminate the NO_x purge. When the efficiency drops below a predetermined value the time that the engine is run in a lean cruise mode is reduced. If the time is reduced below a minimum time interval, a sulfur purge is performed. If sulfur purges are required more often than a predetermined repetition time, the lean cruise mode is terminated and an indicator lamp is energized.

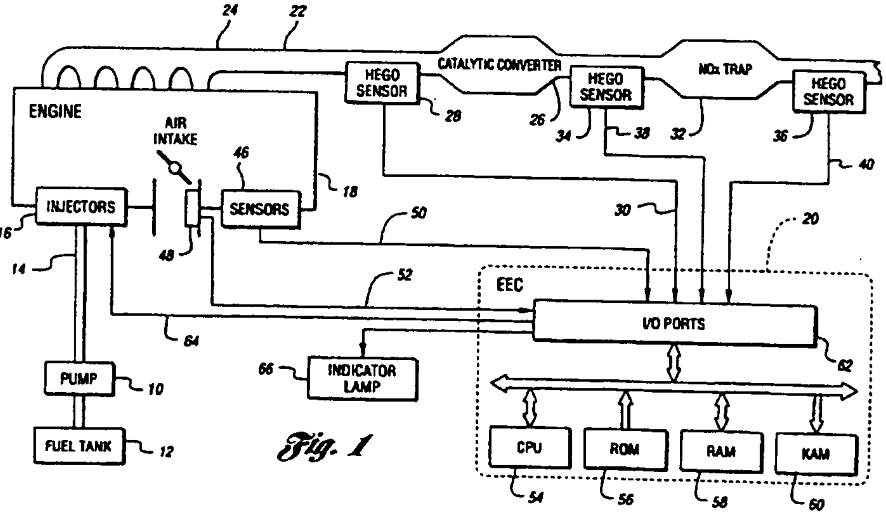

Fig. 1

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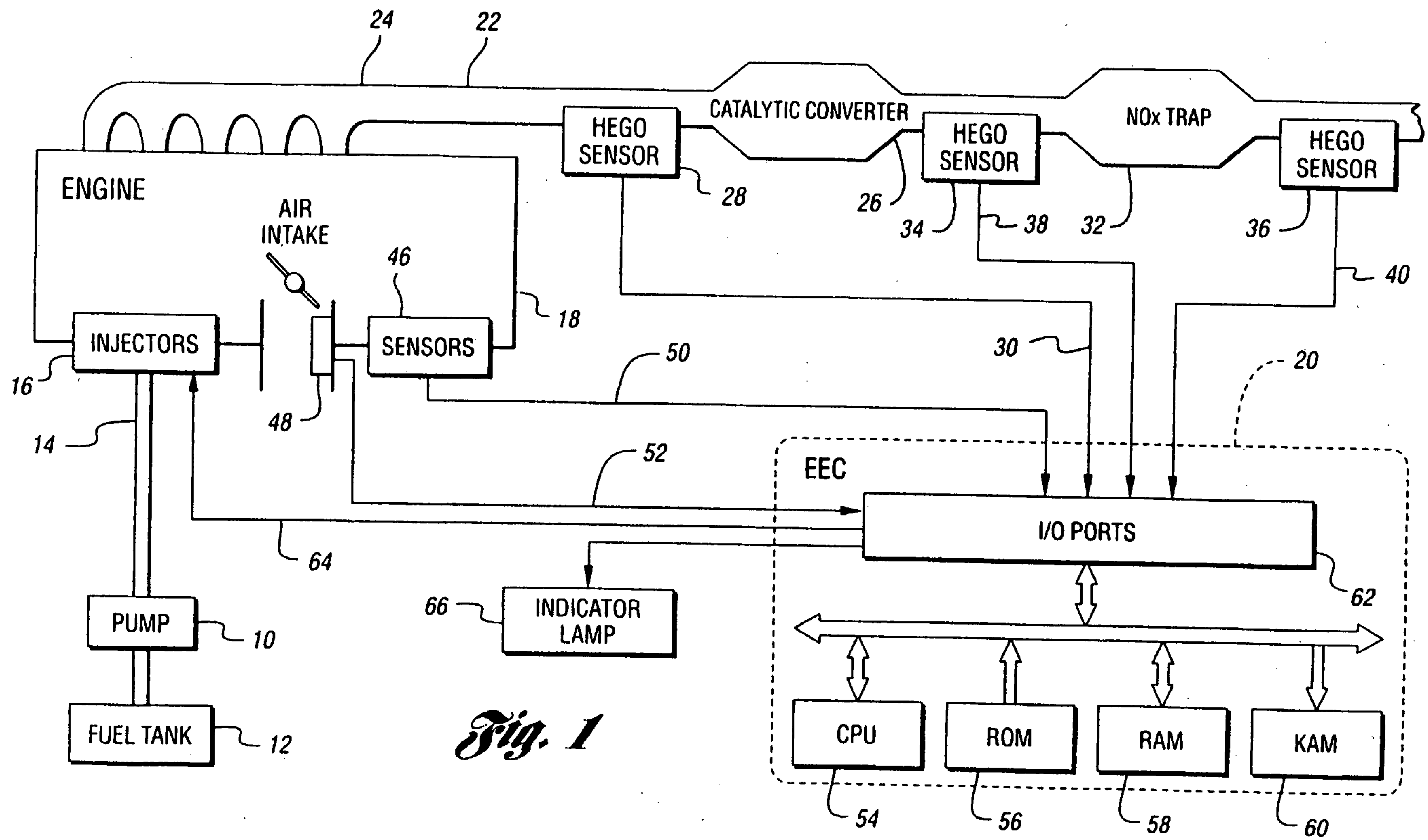
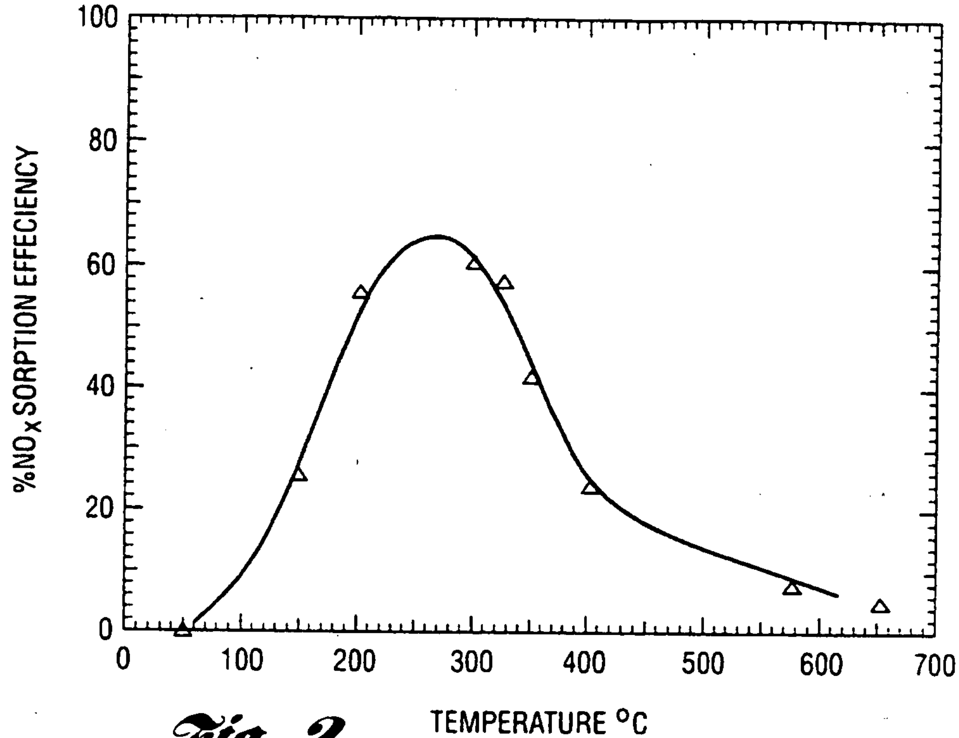
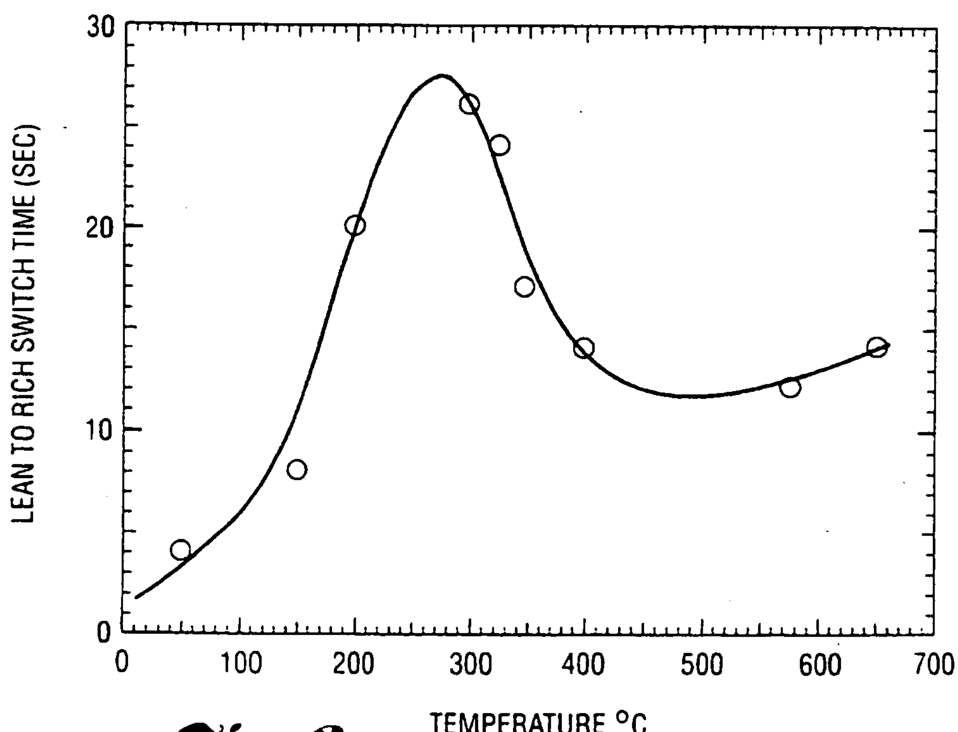

24
22
ENGINE
AIR INTAKE
CATALYTIC CONVERTER
NOx TRAP
HEGO SENSOR
HEGO SENSOR
HEGO SENSOR
28
26
34
38
32
36
40
46
18
INJECTORS
SENSORS
16
48
14
50
30
20
52
EEC
I/O PORTS
64
62
PUMP
10
66
INDICATOR LAMP
FUEL TANK
12
CPU
ROM
RAM
KAM
54
56
58
60

Fig. 1



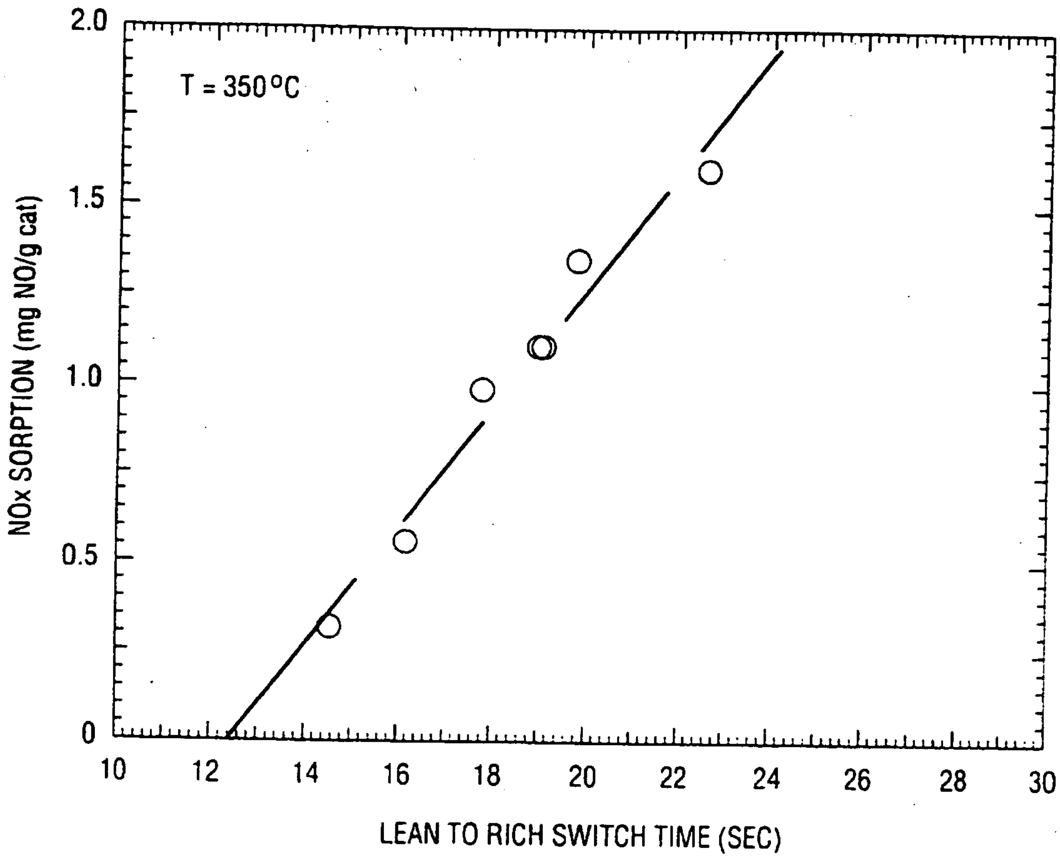
100
80
60
40
20
0
0
100
200
300
400
500
600
700
% NO_x SORPTION EFFECIENCY
TEMPERATURE °C

Fig. 2



30
20
10
0
0
100
200
300
400
500
600
700
LEAN TO RICH SWITCH TIME (SEC)
TEMPERATURE °C

Fig. 3



T = 350 °C
NOx SORPTION (mg NO/g cat)
2.0
1.5
1.0
0.5
0
10
12
14
16
18
20
22
24
26
28
30
LEAN TO RICH SWITCH TIME (SEC)

Fig. 4

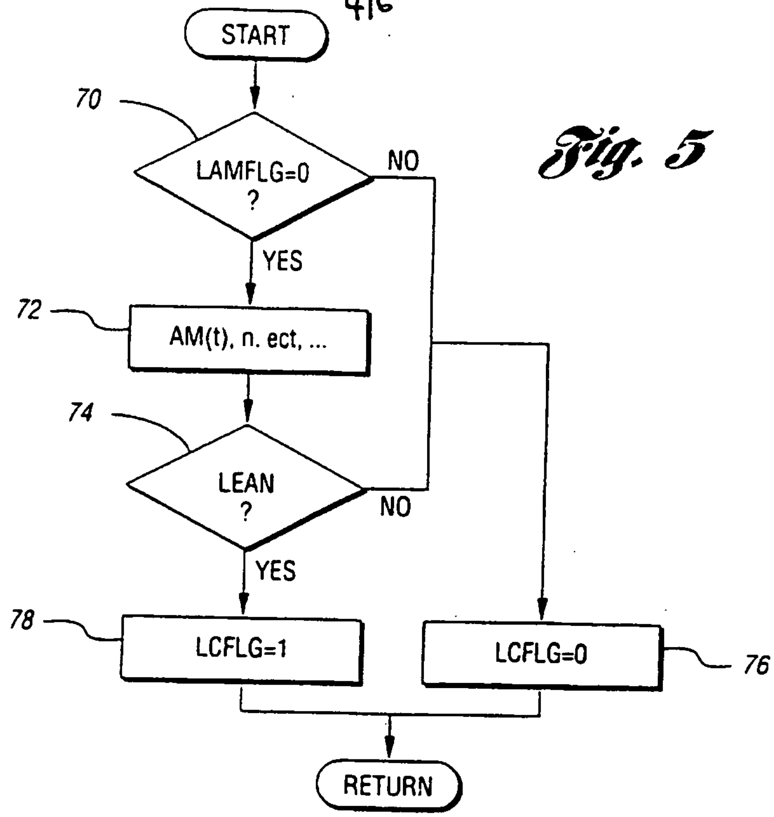

START
70
LAMFLG=0
?
NO
YES
72
AM(t), n. ect, ...
74
LEAN
?
NO
YES
78
LCFLG=1
LCFLG=0
76
RETURN

Fig. 5

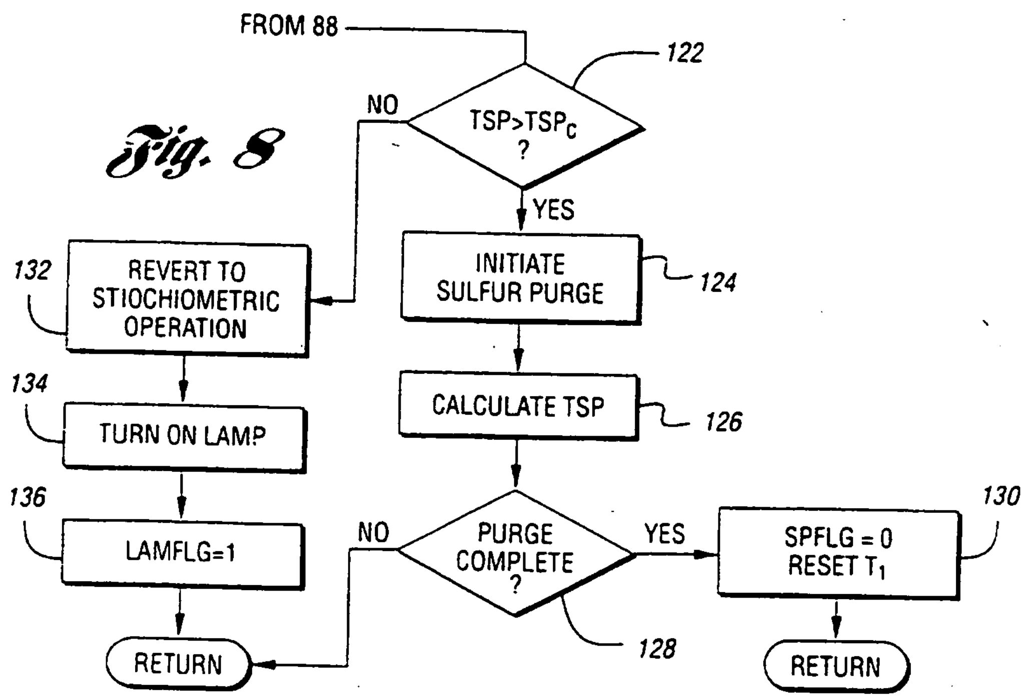

FROM 88
122
NO
TSP>TSP$_C$
?
YES
132
REVERT TO
STIOCHIOMETRIC
OPERATION
INITIATE
SULFUR PURGE
124
134
TURN ON LAMP
CALCULATE TSP
126
136
LAMFLG=1
NO
PURGE
COMPLETE
?
YES
SPFLG = 0
RESET T$_1$
130
128
RETURN
RETURN

Fig. 8

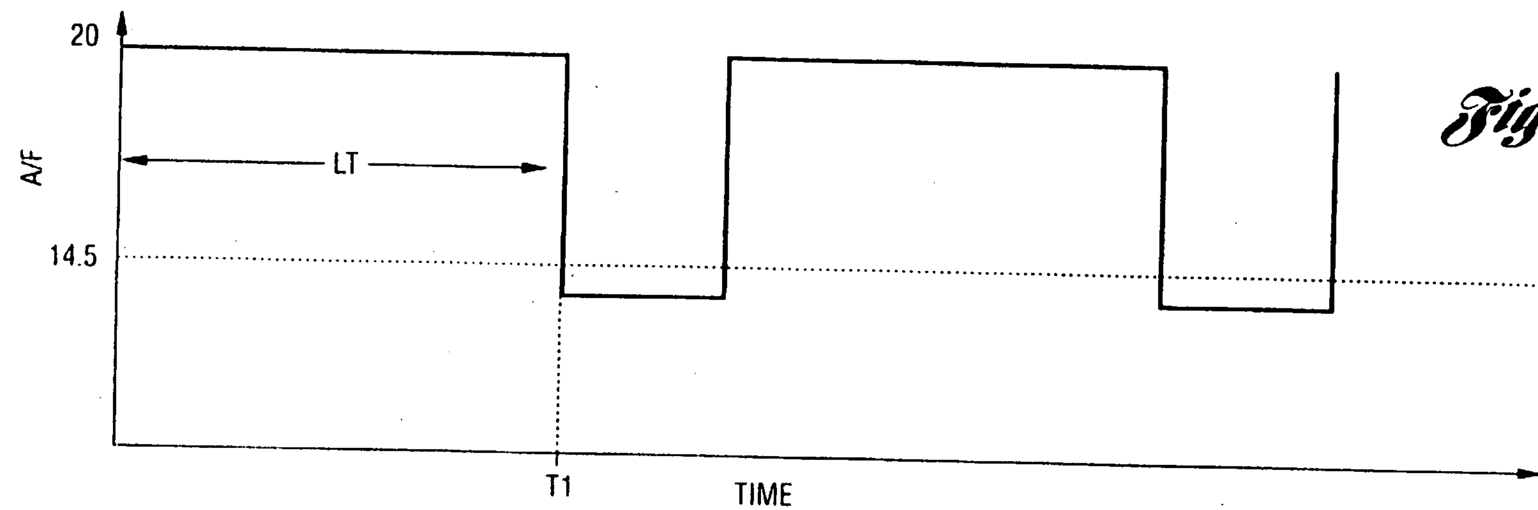

20
A/F
14.5
LT
T1
TIME

Fig. 6a

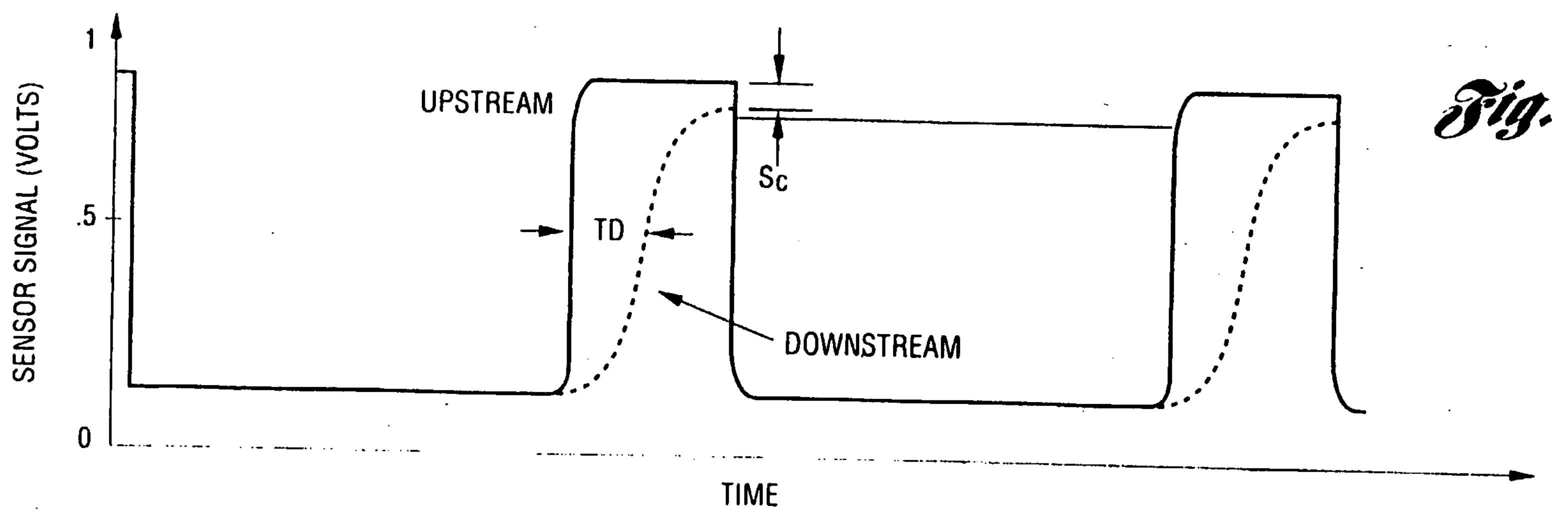

1
.5
0
SENSOR SIGNAL (VOLTS)
UPSTREAM
TD
Sc
DOWNSTREAM
TIME

Fig. 6b

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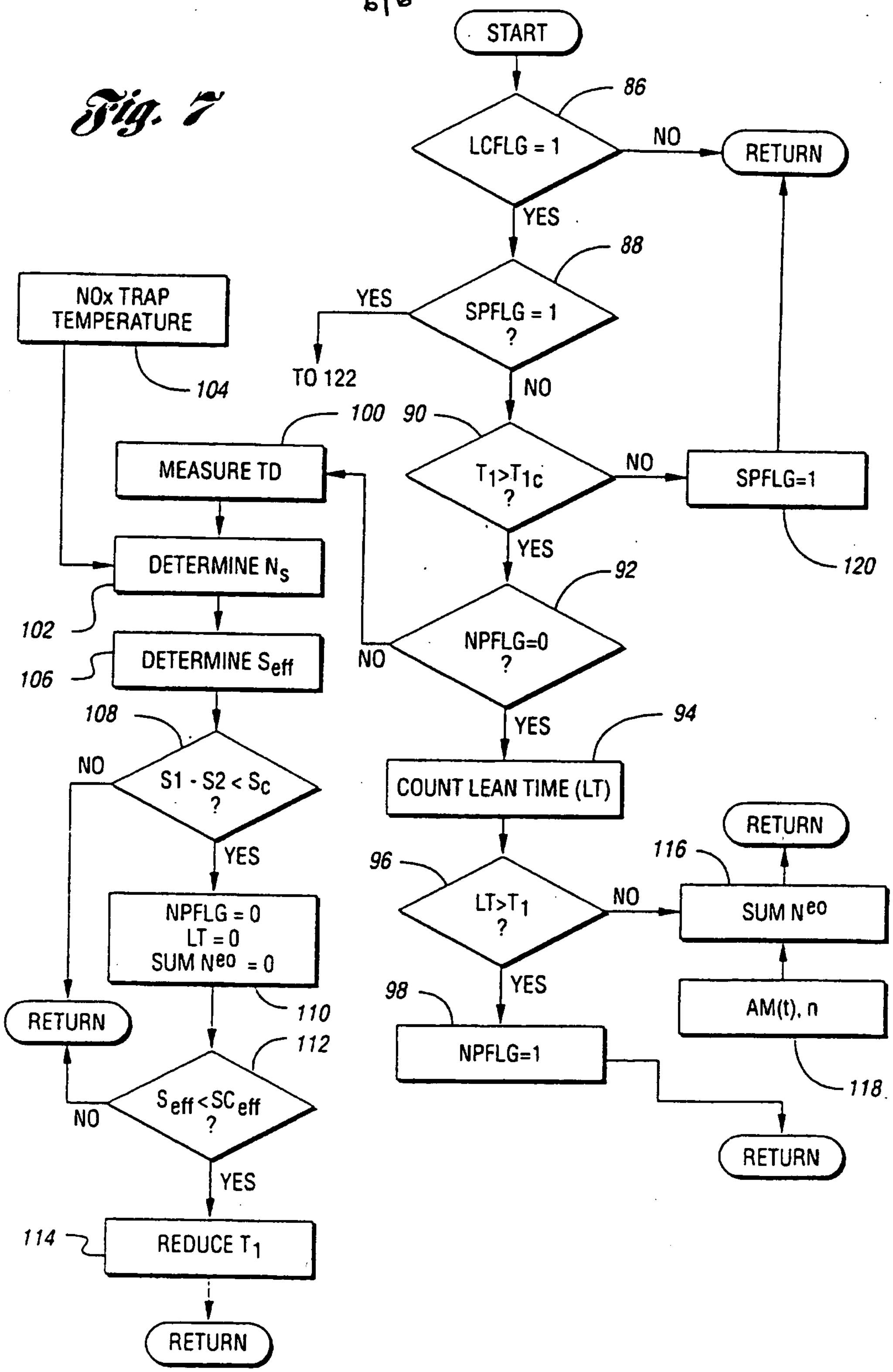

START
LCFLG = 1
86
NO
RETURN
YES
SPFLG = 1 ?
88
YES
TO 122
NO
NOx TRAP TEMPERATURE
104
100
90
MEASURE TD
T1>T1c ?
NO
SPFLG=1
120
YES
DETERMINE Ns
102
92
DETERMINE Seff
106
NPFLG=0 ?
NO
YES
94
108
COUNT LEAN TIME (LT)
NO
S1 - S2 < Sc ?
YES
RETURN
116
96
LT>T1 ?
NO
SUM Neo
NPFLG = 0
LT = 0
SUM Neo = 0
AM(t), n
110
98
YES
RETURN
112
NPFLG=1
118
Seff < SCeff ?
NO
RETURN
YES
114
REDUCE T1
RETURN

Fig. 7

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METHOD FOR MONITORING THE PERFORMANCE OF A NO_x TRAP

This invention relates to monitoring the status and performance of exhaust gas purification devices installed in the exhaust passage of an internal combustion engine.

At present, NO_x traps are considered a potential exhaust after-treatment technology for lean burn engines. NO_x trap technology typically utilizes alkali metal or alkaline earth materials in combination with platinum in order to store or occlude NO_x under lean operating conditions. The mechanism for NO_x storage involves the oxidation of NO to NO_2 over the platinum followed by the subsequent formation of a nitrate complex with the alkaline metal or alkaline earth; under stoichiometric or rich conditions, the nitrate complexes are thermodynamically unstable, and the stored NO_x is released and is catalytically reduced by the excess of CO, H_2, and HCs in the exhaust.

If the NO_x trap deteriorates over time, the ability to trap pollutants degrades with resultant increase in atmospheric pollution. Therefore, it is desirable that NO_x trap technology implemented provide an on-board computer driven diagnostic indication of deterioration or degradation of the NO_x trap beyond a predetermined limit.

In accordance with the present invention, a method and apparatus is provided for making on-board measurements of NO_x trap sorption that permits vehicle on-board computer monitoring and evaluation of NO_x trap performance.

It has been found that during NO_x trap purging, the lean to rich response time (T_{LR}) of a HEGO (Heated Exhaust Gas Oxygen) sensor positioned downstream from the NO_x trap is reduced by an amount which is proportional to the quantity of NO_x stored on the trap. As NO_x sorption efficiency increases, more NO_x is stored on the trap, and the T_{LR} of the downstream HEGO sensor increases as well.

Based on the above discovery, the present invention proposes to use this time interval between the initiation of the purge operation and the switching of the downstream HEGO sensor as an indicator of the amount of NO_x which was stored onto the NO_x trap during the previous lean period of operation. Also, this time delay is used in a diagnostic routine for indicating degradation of the NO_x trap performance to an extent requiring attention by service personnel.

More particularly, in a preferred embodiment of the invention two HEGO sensors, one positioned upstream of the NO_x trap, the other positioned downstream of the NO_x trap are employed. When the engine A/F is reduced from lean to stoichiometric or rich operation to regenerate the NO_x trap (i.e. in order to remove the stored NO_x and subsequently convert it to N_2), the difference between T_{LR} for the upstream and downstream HEGO sensors provides a quantitative measure of the amount of NO_x that was stored on the NO_x trap during the previous lean period of operation. This estimation of the amount of NO_x stored by the trap is related to a predicted amount of NO_x produced by the engine to infer the operating performance or efficiency of the NO_x trap. Also, the output voltage signal differential between the downstream and the upstream HEGO sensor is checked to determined when to terminate the NO_x purge.

If trap sorption efficiency drops below a predetermined efficiency the lean operation time is reduced in an attempt to improve efficiency. If and when the reduced lean time duration drops below a predetermined minimum lean operation time, a sulfur purge of the trap is desirable and is performed.

If the interval between successive sulfur purges becomes less than a predetermined interval, this is indicative of deterioration of the trap beyond that which can be remedied by the normal purging operations. Accordingly, the lean cruise mode of engine operation is terminated and operation reverts to a closed loop

stoichiometric mode and an indicator lamp is energized, so that appropriate remedial action can be taken by the operator.

The invention will now be described further, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is an overall block diagram of the control system of the present invention;

Figures 2 and 3 graphically demonstrate the similar quantitative relationship between $\%NO_x$ sorption efficiency and the lean to rich switch time of a downstream oxygen sensor over a range of temperature;

Figure 4 shows that the lean to rich switch time of a downstream oxygen sensor is substantially directly proportional to the amount of NO_x that is stored on the trap;

Figure 5 is a flowchart depicting the conditions under which a lean cruise mode of engine operation is entered;

Figures 6a and 6b are timing diagrams showing the timing of the initiation and termination of the NO_x purge operation;

Figure 7 is a flowchart depicting the conditions under which the time interval for lean mode is adjusted; and

Figure 8 is a flowchart depicting the conditions under which a sulfur purge is carried out as well as the circumstances under which the lean cruise mode is terminated and an indicator lamp is energized.

Referring now to the drawings and initially to Figure 1, a block diagram of the present invention is shown. A fuel pump 10 pumps fuel from a tank 12 through a fuel line 14 to a set of injectors 16 which inject fuel into an internal combustion engine 18. The fuel injectors 16 are of conventional design and are positioned to inject fuel into their associated cylinder in precise quantities as determined by an electronic engine controller (EEC) 20. The

fuel tank 12 contains liquid fuels, such as gasoline, methanol or a combination of fuel types.

An exhaust system 22, comprising one or more exhaust pipes and an exhaust flange seen at 24, transports exhaust gas produced from combustion of an air/fuel mixture in the engine to a conventional three-way catalytic converter 26. The converter 26 contains catalyst material that chemically alters the exhaust gas to generate a catalyzed exhaust gas. A heated exhaust gas oxygen (HEGO) sensor 28, detects the oxygen content of the exhaust gas generated by the engine 18, and transmits a representative signal over conductor 30 to the EEC 20. A NO_x trap 32 is located downstream of the converter 26 for trapping nitric oxide contained in the exhaust gas exiting the converter. A HEGO sensor 34 detects the oxygen content of the exhaust gas upstream of the trap 28 while a HEGO sensor 36 detects the oxygen content of the exhaust gas downstream of the trap 28. The sensor 34 and 36 transmits signals over respective conductors 38 and 40 to the EEC 20.

Still other sensors, indicated generally at 46, provide additional information about engine performance to the EEC 20, such as crankshaft position, angular velocity, throttle position, air temperature, etc. over conductor 50. The information from these sensors is used by the EEC 20 to control engine operation.

A mass air flow sensor 48 positioned at the air intake of engine 18 detects the amount of air inducted into an induction system of the engine and supplies an air flow signal over conductor 52 to the EEC 20. The air flow signal is utilized by EEC 20 to calculate a value that is indicative of the air mass flowing into the induction system in lbs./min.

The EEC 20 comprises a microcomputer including a central processor unit (CPU) 54, read only memory (ROM) 56 for storing control programs, random access memory (RAM) 58, for temporary data storage which may also be used for counters or timers, and keep-alive memory (KAM) 60 for

storing learned values. Data is input and output over I/O ports generally indicated at 62, and communicated internally over a conventional data bus generally indicated at 64. The EEC 20 transmits a fuel injector signal to the injectors 16 via signal line 64. The fuel injector signal is varied over time by EEC 20 to maintain an air/fuel ratio determined by the EEC 20. An indicator lamp generally indicated at 66 is controlled by the EEC 20 to provide an indication of the condition of the NO_x trap 32 as determined by input data from the various sensors as described more fully hereinafter.

The program stored in ROM 58 implements an air/fuel strategy where the engine is operated in lean mode or relatively high air to fuel ratio (A/F) for fuel economy under certain engine speed/load conditions. During the lean mode, NO_x and SO_x accumulates in the NO_x trap. After predetermined criteria are met, indicative of substantially total sorption of the trap 32, the A/F is switched to a relatively rich mixture to purge the trap of NO_x. After the purge node is completed the EEC returns to the lean mode of operation. Alternatively, the EEC program may call for a stoichiometric mode of operation instead of the rich mode for purging the trap of NO_x.

Referring now Figures 2, 3, and 4, the relationship between lean to rich switch time (T_{LR}) of a HEGO sensor placed downstream of a NO_x trap and the quantity of NO_x stored on the trap is graphically illustrated. Figures 2 and 3 contrast NO_x trap sorption efficiency as a function of temperature to the corresponding lean to rich switch time (T_{LR}) of a HEGO sensor placed downstream of the NO_x trap. The NO_x trap sorption efficiency and the downstream HEGO's T_{LR} exhibit very similar qualitative behaviors. As NO_x sorption efficiency increases, more NO_x is stored on the trap, and the T_{LR} of the downstream HEGO sensor increases as well.

Figure 2 shows the average NO_x sorption efficiency as a function of temperature during a 5 minute lean cycle for a conventional strontium based NO_x trap. With increasing

temperature, NO_x sorption efficiency first increases, reaches a maximum level at approximately 300-350°C, and then decreases. These measurements were made in a laboratory flow reactor with a simulated exhaust gas consisting of 10%H_2O, 10% CO_2, 500ppm NO_x, 7%O_2, in a balance of N_2. To purge or regenerate the NO_x trap, the O_2 in the exhaust gas was turned off and replaced with 0.58% CO. The space velocity was 30,000hr-1.

Figure 3 shown a graph of the corresponding lean to rich switch time (T_{LR}) for a conventional Exhaust Gas Oxygen Sensor (EGO) placed downstream of the NO_x trap. T_{LR} is defined as the time period between the initiation of the NO_x trap purge and the observation of a minimum 0.5 volt sensor output signal. The NO_x trap sorption efficiency and T_{LR} display very similar qualitative behaviors. As NO_x trap sorption efficiency increases, more NO_x is stored onto the trap, and the T_{LR} of the downstream EGO sensor increases as well. It is believed that the NO_x which is stored onto the trap behaves very much like stored oxygen and simply reacts with the CO and H_2 in the exhaust during purging hence delaying rich breakthrough.

Figure 4 shows a graph of NO_x storage as a function of T_{LR} at 350°C. The lean operating period was varied in order to vary the quantity of NO_x stored onto the trap. At a given temperature, the T_{LR} which is observed during purging of the NO_x trap is seen to be directly proportional to the quantity of NO_x which was stored onto the trap during the previous lean period of operation. The present invention utilizes this relationship between NO_x sorption and T_{LR} to control trap purge time, to determine whether the time interval of lean operation should be reduced, and to determine when the trap should be replaced. Also, this relationship is used to determine when to de-sulfate the trap to rid the NO_x trap of SO_x.

Referring now to Figure 5, a flowchart depicting the criteria for entering the lean cruise mode of operation is shown. The lean cruise mode of operation includes an open

loop fuel control mode where the engine is operated with a lean fuel mixture of for example 20 parts air to 1 part fuel. The lean cruise mode of operation also includes a closed loop fuel control mode, which is periodically entered from the open loop mode, where the engine is operated at a stoichiometric air fuel ratio of about 14.5 to 1 for a time interval sufficient to purge the NO_x trap of NO_x prior to return to the lean mode. There is a flag LCFLG that reflects the status of the lean cruise mode. While in the lean cruise mode the engine is normally operating in an open loop lean mode and is periodically placed in a closed loop stoichiometric mode or slightly open loop rich mode for purging the NO_x.

At block 70, an indicator lamp flag LAMFLG is checked. This flag is set whenever the EEC 20 determines that the NO_x trap has degraded to a point where the normal SO_x purging operations are no longer sufficient and the $N0_x$ trap requires further attention and may need to be replaced. Such a condition would be indicated to the vehicle operator by the energized state of the indicator lamp 66 and the occurrence of NO_x degradation would be logged in the keep alive memory 60. IF LAMFLG is reset(0), indicating normal NO_x trap operation, then at block 72 the air mass inducted into the engine, as well as other engine operating conditions, such as speed and engine coolant temperature, are measured to determined the proper engine air fuel ratio (A/F). If degradation of the NO_x trap has occurred (LAMFLG=1), or if conditions are such that lean operation is not desirable, as determined by the decision block 74, then a lean cruise flag LCFLG is reset(0) at block 76 and the subroutine returns to the main program. Otherwise, the lean cruise flag LCFLG is set(1) at block 78 and the subroutine returns to the main program. The lean cruise mode of operation includes operating at a lean A/F for a length of time T_1, during which time the engine speed and load are used to estimate the cumulative amount of NO_x produced by the engine. After the time interval T_1 has expired, a purge of the NO_x trap is

performed by operating the engine at a relatively rich A/F for a purge interval before returning to the relatively lean operation.

A timing diagram of the NO_x purge operation is shown in Figures 6a and 6b. Figure 6a shows an air/fuel ratio schedule as a function of time, while the engine is operation in a lean cruise mode of operation at an open loop air/fuel ratio of 20. When lean time LT becomes greater than T1 a purge of the trap 32 is appropriate so the air/fuel ratio is stepped from a lean value to a slightly rich value, where an air/fuel ratio of 14.5 represents stoichiometry. When this occurs the upstream sensor 34 switches immediately from low voltage to a high voltage, as shown in Figure 6b. As indication by the dotted line, the switching of the downstream sensor is delayed by the amount TD. The time delay required for the downstream sensor 36 to reach a predetermined voltage, for example, one-half volt as shown in Figure 6b is measured (block 100). When the output voltage difference between the downstream sensor 36 and upstream sensor 34 reaches a predetermined value S_c (block 108) the NO_x purge is terminated and lean operation is resumed.

Referring now to Figure 7, a flowchart depicting the criteria for purging the NO_x trap and the calculation of NO_x storage efficiency, is shown. At block 86, LCFLG is checked to determined if the system is being operated in a lean cruise mode. If not, the routine returns to the main program. If so, a sulfur purge flag SPFLG is checked at decision block 88. If SPFLG is set(1) then a sulfur purge of the trap is initiated as will be described hereinafter. If SPFLG is reset(0), the time duration of the lean mode of operation T_1, is compared with a predetermined minimum time period T_{1c}. Unless T_1 is greater than this predetermined time interval T_{1c}, lean cruise operation may need to be terminated. The time interval T_1 is initially a predetermined value and will remain so as long as NO_x trap storage efficiency remains above a predetermined or required

efficiency value, but T_1 will be reduced as explained below in order to maintain the required efficiency. If it is determined at block 90 that T_1, is not greater than the predetermined time period T_{1c}, this may indicate that the NO_x trap is deteriorated due to the adsorption of SO_x, an undesirable but unavoidable process. Accordingly, the sulfur purge flag is set and the lean and NO_x flags are reset at block 120 and the operation returns to the main program. The next time through this routine a sulfur purge will be called for at the decision block 88.

If T_1 is greater than T_{1c}, then the conditions of a NO_x purge flag (NPFLG), is checked at decision block 92. If the NO_x purge flag is reset, that is, the engine is operation in a lean mode, lean time LT is incremented at block 94 and compared to T_1 at block 96. If the lean time is not greater than the predetermined time period for lean operation as determined by the block 96, then an estimate of the amount of NO_x which has been introduced to the trap since the last purge is made in block 116. SUM N^{e0}, determined in block 116, is a prediction of cumulative NO_x produced by the engine based on air mass inducted into the engine and engine speed as input from block 118. If, on the other hand, the measured lean operating time is greater than the set time period for lean operation T_1, as determined at block 96, the NPFLG flag is set as shown at block 98 and the NO_x purge operation is begun by switching from a lean mode to a relatively rich A/F. The next time through the loop at block 92 the NO path will be taken.

During the NO_x purge, the time delay that occurs between switching of the front and rear EGO sensors, due to NO_x accumulation, is measured at block 100. Based on this time delay, the amount of NO_x stored on the trap N_s is determined at block 102 as a function of the trap temperature (Figure 4), which is input from block 104. The trap temperature may be obtained in several known ways such as from a temperature sensor or based on sensed air mass or estimated by way of another input.

The NO_x storage efficiency S_{eff} is determined at block 106 based on the ratio N_s/SUM N^{e0}. In other words, storage efficiency is ratio of the amount of NO_x stored in the trap to the amount of NO_x generated by the engine. At decision block 108, the voltage S2, of the downstream HEGO sensor 36 is subtracted from the voltage S1, of the upstream HEGO sensor 34 and the difference is compared to a predetermined difference S_c to determine whether it is time to terminate the NO_x purge. As soon as the difference drops below the predetermined difference value, the purge may be considered complete and is terminated and the NO_x purge flag NPFLG is reset(0), the lean cruise time counter or timer LT is reset, and the predicted NO_x value SUM N^{eo} is reset at block 110.

If the NO_x storage efficiency is less than a predetermined NO_x storage efficiency SC_{eff} as determined by the block 112, then the time period for lean operation, T_l, is reduced toward T_{1c}, by a predetermined amount, at block 114. If the lean time interval has been reduced below the predetermined time period T_{1c} as determined by the block 90 then the sulfur purge flag (SPFLG) is set as indicated in the block 120. With SPFLG = 1, the next time through this routine a sulfur purge will be called for at the decision block 88.

Referring now to Figure 8, the subroutine for carrying out a sulfur purge and on-board NO_x trap diagnostics is shown. Sulfur purge is accomplished by raising the NO_x trap temperature to a predetermined level, for example above 550 degrees C, while exposing the NO_x trap to a rich exhaust gas mixture. Additional air from a separate air supply and pump may be introduced under EEC control to achieve desired trap temperature in order to generate an exotherm on the NO_x trap 32 and hence achieve the desired temperature.

If the lean cruise flag (LCFLG) is set(1), and the sulfur purge flag (SPFLG) is set(1), as determined by blocks 86 and 88 of Figure 6, a sulfur purge is initiated at block 124, unless the time period between successive sulfur purges (TSP) is less than a predetermined time period (TSP_c) as

determined by the block 122. At block 126 the time since the last sulfur purge (TSP) is calculated. When the purge is completed as determined by block 128, the sulfur purge flag (SPFLG) is reset(0) at block 130 and the subroutine returns to the main program. Completion of sulfur purge would be based on the trap 32 being above a threshold temperature for a predetermined time period or on other criteria. On the other hand, if the time period between sulfur purges is less than the predetermined time period TSP_C, this frequent need to perform a SO_x purge is an indication that the trap is not being properly purged and may be defective. In this event the system reverts to a stoichiometric operation at block 132, the indicator lamp is energized at 134, and the associated flag (LAMFLG) is set at 136. This will cause the lean cruise flag LCFLG to be reset(0) at block 76 (Figure 5) the next time a decision is called for at block 70. Thus, a diagnostic lamp is energized whenever the NO_x trap exhibits an apparent permanent loss in activity which is not alleviated by the NO_x and SO_x purging operations normally intended to revitalize the trap.

While two HEGO sensors 34 and 36 are shown, the sensor 34 could be eliminated. In this particular case, the time interval measured at block 100 would be simply the time delay between the initiation of the NO_x purge (switching engine A/F ratio from lean to rich or stoichiometric) and the lean to rich switch of the rear HEGO sensor 36. Also, a minimum output signal or voltage of sensor 36 would be checked at block 108 to determine that an adequate NO_x purging had been completed. Further, the NO_x purging operation may commence based on other criteria than a predetermined time interval in lean mode. This change would involve a modification of the operations performed at blocks 90, 96 and 114 to reflect the new criteria.

CLAIMS

1. A method of monitoring performance of a NO_x trap disposed in an exhaust passage of an internal combustion engine, comprising the steps of:

switching the operation of said engine from a relatively lean mode of operation to a relatively rich mode of operation to purge said NO_x trap;

detecting a change in the content of the exhaust gas composition at a predetermined exhaust passage location; and

determining the amount of NO_x stored onto the NO_x trap during the previous lean period of operation as a function of the elapsed time between said switching step and said detecting step.

2. A method as claimed in Claim 1, wherein said predetermined location is downstream of said trap.

3. A method as claimed in Claim 2, wherein the change detected is in the oxygen content of the exhaust gas.

4. A method as claimed in Claim 1, wherein the change detected is in the oxygen content of the exhaust gas.

5. A method as claimed in Claim 2, further comprising the step of termination said purge when the exhaust gas content at said location satisfies a predetermined criteria.

6. A method as claimed in Claim 5, wherein said predetermined criteria is the exhaust gas oxygen content at said location reaching a predetermined value.

7. A method as claimed in Claim 5, further comprising the steps of:

estimating the amount of NO_x produced by the engine since the last purge; and

determining the sorption efficiency of said NO_x trap by dividing the quantity of NO_x stored onto the trap by the estimated quantity of NO_x produced by the engine.

8. A method as claimed in Claim 7, including the further step of reducing the time duration of the lean mode of operation if the sorption efficiency is less than a predetermine minimum efficiency.

9. A method as claimed in Claim 8, including the further step of providing a performance indicator if the time duration of said lean mode of operation is reduced below a predetermined minimum time interval.

10. A method as claimed in Claim 9, including the further step of carrying out a sulfur purge operation if the duration of said lean mode of operation is reduced below a predetermined minimum time interval.

11. A method as claimed in Claim 10, including the further steps of energizing an indicator if the time interval since the last sulfur purge is less than a predetermined time interval.

12. A method as claimed in Claim 11, including the further step of reverting to a stoichiometric mode of engine operation.

13. A system for monitoring performance of a NO_x trap disposed in an exhaust passage of an internal combustion engine, comprising:

an exhaust gas sensor disposed downstream from said trap;

means for generating a command to switch the operation of said engine from a relatively lean A/F to a relatively rich A/F to purge said NO_x trap;

means for detecting the switching of said sensor from a first to a second state in response to the exhaust gas content;

means for measuring the time interval between the initiation of said command and the detection of said switching; and

means for determining the sorption of said NO_x trap as a function of said time interval.

14. A system as claimed in Claim 13, wherein said means for generating a command terminates said relatively rich A/F and initiates said relatively lean A/F thereby terminating purging of said NO_x trap when the voltage output of said sensor reaches a predetermined value.

15. A system for monitoring performance of a NO_x trap disposed in an exhaust passage of an internal combustion engine, comprising:

a first exhaust gas oxygen sensor disposed upstream from said trap;

a second exhaust gas oxygen sensor disposed downstream from said trap;

said first and second sensor producing respective outputs indicative of the oxygen content of the exhaust gas;

air fuel ratio control means for switching the operation of said engine from a relatively lean mode of operation to a relatively rich mode of operation to initiate a purge of said NO_x trap;

said control means detecting the switching of said first and second sensors from a relatively high exhaust gas oxygen content state to a relatively low exhaust gas oxygen content state following switching to said relatively rich mode of operation;

said control means determining the sorption of said NO_x trap as a function of the temperature of said trap and the time interval between the switching of said first and second sensors.

16. A system as claimed in Claim 15, wherein said control means terminates said purge when the difference between the outputs of said first and second sensor is less than a predetermined value.

17. A system as claimed in Claim 16, wherein said control means estimates the amount of NO_x produced by the engine as a function of engine speed and load; and

said control means determines the sorption efficiency of said NO_x trap as a function of said time interval and the estimate of the NO_x produced by the engine.

18. A system as claimed in Claim 17, wherein said control means reduces the time duration of the lean mode of operation if the sorption efficiency is less than a predetermined minimum efficiency.

19. A system as claimed in Claim 18, wherein said control means carries out a sulfur purge operation if the time duration of said lean mode of operation is below a predetermined minimum time interval and the time interval since the last sulfur purge is greater than a predetermined time interval.

20. A system as claimed in Claim 19, wherein said control means reverts to a relatively stoichiometric mode of engine operation and causes an indicator to be energized if the time interval since the last purge is not greater than said predetermined time interval.

21. A method of monitoring the status and performance of a NOx trap substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

22. A system for monitoring the status and performance of a NOx trap substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

The Patent Office

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Claims searched:	1-22	**Date of search:**	16 January 1998

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Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): G1N NBMH.

Int Cl (Ed.6): F01N 7/00

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Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A, P	EP 0 735 250 A (Toyota Jidosha K K)	
A, P	EP 0 733 786 A (Toyota Jidosha K K)	
A	EP 0 690 213 A (Toyota Jidosha K K)	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.